Cold Atmospheric Plasma Technology for Decontamination of Space Equipment

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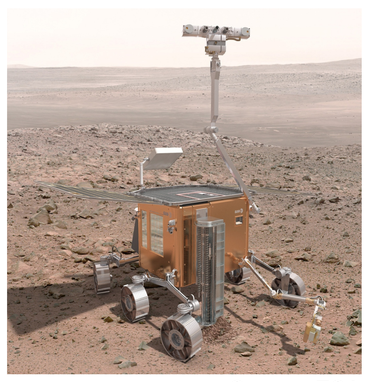
Abstract

Future planned space expeditions require the compliance of the planetary protection policy [1]. Therefore, COSPAR (Committee on Space Research) defines five categories of missions with different decontamination standards [1].
The common sterilization methods like dry heat and H_2O_2 could have a negative effect on heat-sensitive materials [2].
In medicine, low-temperature plasma is already used for sterilization of medical equipment and proved its positive effect to human skin.



Source: ESA

First studies showed that cold atmospheric plasma (CAP) technology is a very fast alternative to inactivate microorganisms on surfaces [3].
A follow-on study is planned to reach a high application level for the sterilization of space equipment using CAP funded by „Bayrisches Wirtschaftsministerium“.

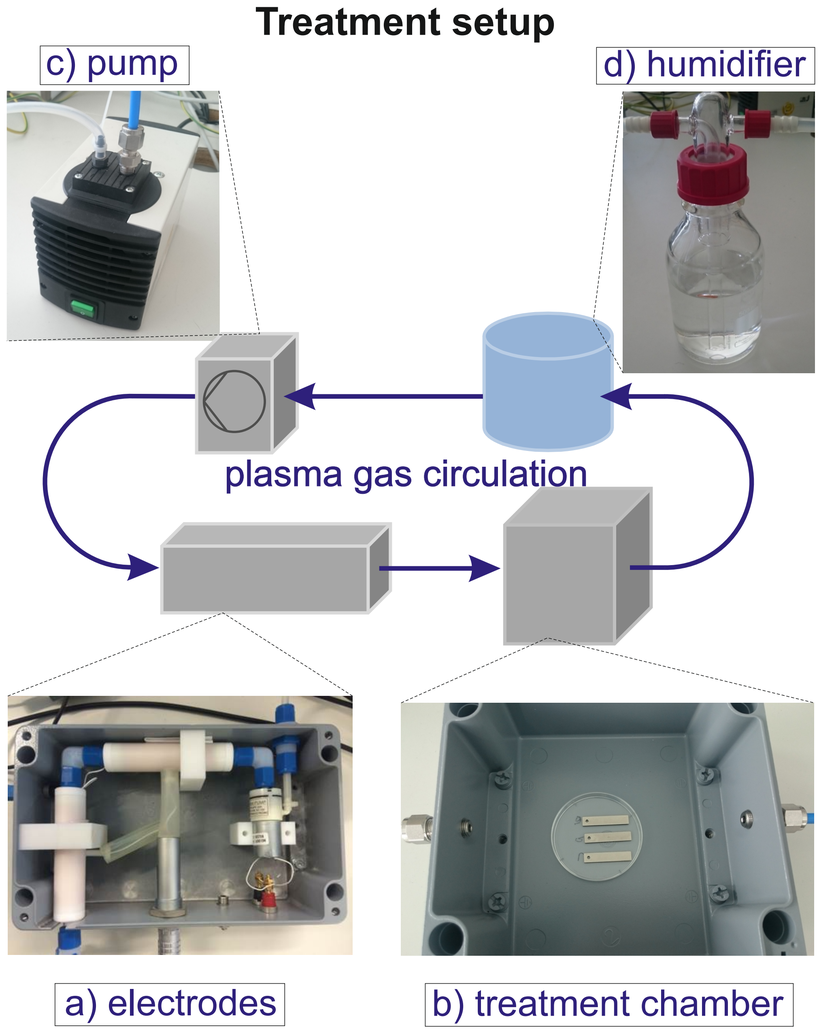
- Utilization of a closed plasma cycle including long living reactive species.
- Evaluation of CAP conditions for maximal sporicidal effect and analysis of this effect by increasing the treatment volume.

Material and Methods

Technical description and parameters

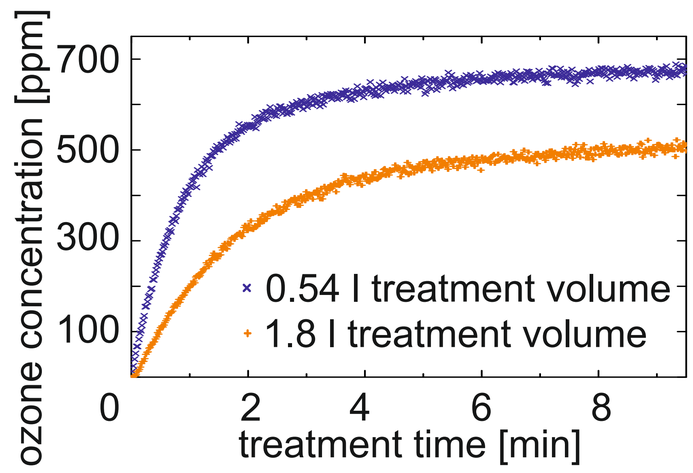
- Use of two cylindrical plasma electrodes with 12 mm diameter, manufactured by terraplasma GmbH (a)
- Flow rate of 5.5 l/min is generated by an external and chemical resistant pump (c)
- Treatment chamber 1 dimensions: ~ 7.4 x 8.0 x 9.1 cm³ = 0.54 l (b)
- Treatment chamber 2 dimensions: ~ 14.6 x 8.2 x 15.0 cm³ = 1.80 l (b)
- Sample treatment dimensions: 3.2 x 0.62 cm² (b)
- Gas wash bottle for moistening the contained air / plasma gas close to 99% relative humidity (d)
- Specific conditions for sample treatment:
  - frequency: 10 kHz
  - voltage: 6.4 kVpp
  - power: ~ 3.92 W
  - treatment time 0.54 l: 0, 2.5, 5, 7.5 and 10 min
  - treatment time 1.8 l: 0, 2.5, 5, 7.5,10, 15 and 20 min

Treatment setup

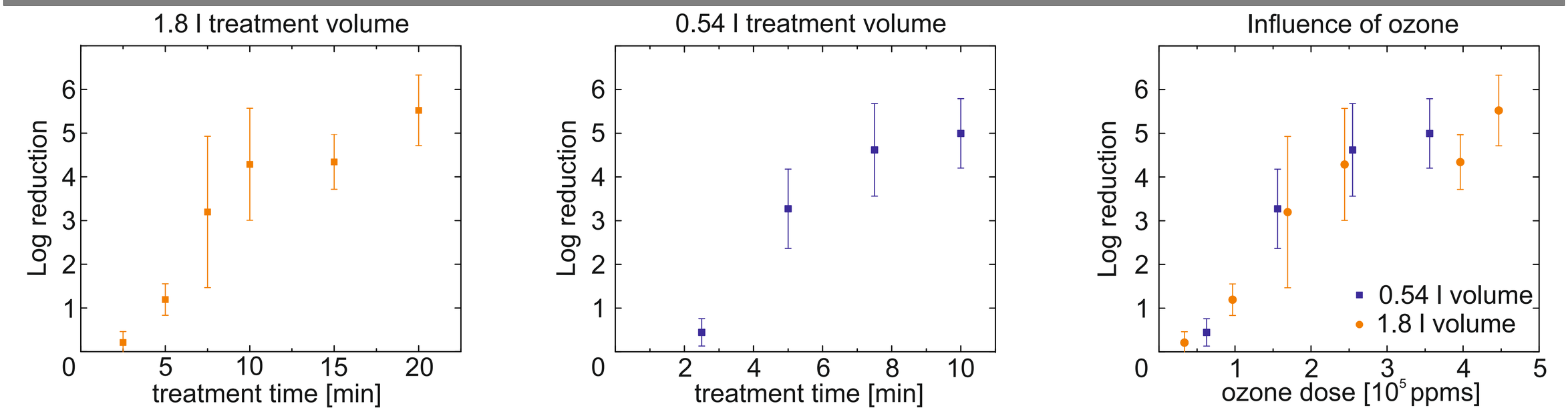


Test description

- Samples are SIMICON bio-indicators with average plate count of 2.6 x 10^6 cfu of *B. atrophaeus* spores ATCC 9372 on V4A stainless steel plates.
- Treatment of 3 samples at once located in a petri dish lid (b)
- Extensive protocol is necessary to solve the treated spores in liquid (alternating ultrasound and shaking)
- Filtration process allows a detection limit of 6-log reduction
- Different ozone concentrations:



Results



Conclusion and Outlook

- New investigations demonstrate an inactivation of *B. atrophaeus* about 5 log after 10 min treatment in a 0.54 l treatment volume and about 5.5 log after 20 min treatment in a 1.8 l treatment volume. This result can be explained by the lower ozone concentration in the large treatment volume (ozone saturation in 0.54 l volume after 4 min; ozone saturation in 1.8 l volume after 6 min).
- The predominant ozone concentration during a certain time span is responsible for the percentage of spore inactivation.
- Compared to former results of Shimizu et. al. (inactivation of 3 - 4 log after 30 min treatment time) [1], the new setup provides a significant improvement of the inactivation process. Additionally, no ozone capture device is needed.
- Further activities will concentrate on larger treatment volumes and on the influence of different plasma and humidity conditions to the samples.

[1] M.Hofmann; P.Rettberg; M.Williamson, 2010 Protecting the Environment of Celestial Bodies *38th COSPAR Scientific Assembly*
[2] T.G. Klaempfl, 2012 Cold Atmospheric Air Plasma Sterilization against Spores and Other Microorganisms of Clinical Interest Applied and Environmental Microbiology
[3] S.Shimizu, 2014 Cold atmospheric plasma - A new technology for spacecraft component decontamination *Planetary Space Science*

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